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07 July 2003

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The present invention relates to a method for flux deposition in conjunction with vapour phase soldering, where a solder heating medium is evaporated by heating forming a vapour, which vapour heats elements to be soldered partly by condensation to a temperature above a soldering temperature, which leads to soldering of elements, which soldering process leads to evaporation of flux and other chemical substances.

The present invention also relates to an apparatus for flux deposition connected to a soldering machine, which soldering machine comprises a solder heating medium evaporated by heating means forming a vapour that heats elements to be soldered by heat transfer and by condensation, which apparatus comprises means for condensation, of a vapour containing flux where pumping means circulate vapour containing flux through the condensation means, where the condensation means comprises heat exchangers for cooling the vapour for flux condensation.

US 6,382,500 describes a semiconductor soldering device. In a solder reflow furnace, flux is vaporized and carried to the furnace exhaust pipe. The flux condenses on the walls of the exhaust pipe and drips back into the furnace thereby contaminating production parts. A solder reflow furnace with a flux effluent collector prevents flux drip-back. The flux effluent collector has an exhaust gas heater that maintains flux effluent in a gaseous state, a flux cooler, to subsequently condense flux, and a flux condensation region where the flux condenses. The flux condensation region is offset from the furnace's exhaust opening so that condensed flux cannot drip back into the furnace.

US 5,611,476 describes a solder reflow convection furnace employing flux collection and heating to minimize flux and solvent build up and gas densification to reduce input gas flow. As solder melts in the furnace, an effluent of vaporized flux is driven off and can condense on cooler components. To minimize such condensation, the gas is directed through a cooling system in which the flux condenses, and the cooled, purified gas is directed into the furnace's product cooling section. In another embodiment, in which the gas in the furnace is recirculated, a cooling coil is located upstream of the recirculating gas mover to heat the primary gas. The vaporized flux

condenses on the cooling coil, which can be readily removed and replaced. In another aspect of the invention, in which furnace employs a gas amplifier, the recirculating gas is cooled prior to reentry into the heating chamber, which increases its density and removes flux by condensation.

The above documents describe inventions by which it is possible to remove flux from a furnace in which a solder process takes place. Used in combination with infrared reflow soldering, removing of flux takes place in an efficient way. But used in vapour phase reflow soldering furnaces, where a solder heating medium is evaporated by heating means forming a vapour that heats and solder electronic boards by condensation of the vapour, the vapour is drawn out of the furnace. By contact to the cooling surfaces in the cooling system, the vapour is caused to condense together with the flux, thereby forming a mixture of liquid solder heating medium and liquid flux. It is important that separation of liquid flux and liquid solder heating medium takes place in such a way that solder heating medium is not lost.

The non-published Danish patent application No. PA 2002 00906 filed by the same applicant concerns a vapour face soldering machine but this invention does not comprise means for flux separation.

The scope of this invention is to remove flux from a vapour phase solder furnace without losing solder heating medium.

This can be achieved by a method as described in the introduction, which method is modified in such a way that vapour of solder heating medium containing flux and other chemical substances is drawn into a closed circuit in time periods between and after soldering processes, where the closed circuit comprises at least a first condensation process and a second condensation process, which first and second condensation processes take place at a first high and a second lower temperature, and liquid solder heating medium is returned to the vapour phase soldering process.

Hereby it can be achieved that after completion of a soldering process where, for example, a printed circuit board has been fully soldered, the flux, which was contained

in the soldering paste placed on the board, to a large extent is evaporated and consequently mixed up with the solder heating medium. Thus after completion of the soldering process, a mixture of flux and solder heating medium is sucked out of the soldering chamber and into a closed circuit in which purification of the solder heating medium takes place. This purification is done by removal of the flux content from the mixture by passing it through condensation means, where condensation at a first high temperature takes place by which most of the flux contained in the mixture is condensed. In this first condensation process, the solder heating medium itself is also partly condensed. The liquid substance resulting from the condensation process drips down from the condensation means and into a collector part thereby conducting the rest of the solder heating medium, which still may contain a small content of flux, to a second condensing means where the condensation takes place at a lower temperature than in the first condensation process. It is ensured that almost all solder heating medium is condensed in that the temperature of the condensation process is lower than the boiling temperature of the solder heating medium. The result of this process is that that most of the flux that has evaporated during the soldering process is now collected inside a closed circuit and as such totally removed from the soldering process.

The first high condensation temperature depends on the condensation temperature of the flux, whereas the second lower temperature depends on the condensation temperature of the solder heating medium. If it is possible to define the exact condensation temperature of the flux, it will be possible to effect almost full condensation of flux at the first condensation temperature. If the difference between the condensation temperature of the solder heating medium and the condensation temperature of the flux is sufficiently high, it is possible to fully separate the two gases into different liquids. In practice, however, the flux has a very complex composition where the condensation can take place over a relatively large temperature range. Probably both flux and solder heating medium will be condensed at the second (lower) condensation temperature.

The method may also comprise the use of a protective gas during the soldering process, which protective gas is mixed with the vapour. The use of the protective gas is important during the soldering process because the protective gas prevents oxygen

from getting into contact with the melted solder. But also before melting of the soldering material, the temperature is high. If solder paste is used, which may have a relatively large surface, oxidation may start already during the preheating of the devices to be soldered. The protective gas will be mixed with the vapour of the solder heating medium during the whole process. After completion of the soldering process, vapour continues to be drawn out of the chamber, and the mixture of flux, vapour of the solder heating medium and protective gas is led through the condensing units. The condensing units will remove flux and solder heating medium and leave almost purified protective gas.

The protective gas can be heated by heating means to a temperature below the condensation temperature of the vapour after it has passed through the condensing processes and before the protective gas is returned to the soldering chamber. The condensing processes and the heating process take place in time periods before and after soldering of the elements. If the protective gas just is returned to the soldering zone without any heating, the newly soldered printed circuit boards may suffer temperature shocks. To avoid temperature shocks, the protective gas is heated afterwards to a temperature slightly below the condensation temperature of the solder heating medium. This leads to condensation of the vapour in the soldering zone, but with only limited cooling effect on the printed circuit boards. The condensation of the vapour occurs rapidly, so in only few seconds all vapour in the soldering zone has been condensed and will fall down to the bottom as drops. Seen from the outside, it looks as if the vapour is rapidly lowered to a level below the printed circuit board. Afterwards can the printed circuit board be removed from the soldering zone through a door. In this way it is achieved that most of the solder heating medium is removed from the soldering zone at the time when the door is opened, and only very limited amounts solder heating medium are lost to the environment.

The condensed heating medium can be returned to the soldering process through a flux-depositing trap comprising cooling means for further flux condensation and flux solidification. This provides a very efficient removal of flux contained in the liquid solder heating medium, especially if the temperature is caused to fall gradually during a flow path for the liquid. By placing a large number of steps that the liquid has to

pass, solidified flux will be collected on the steps and may adhere to the surfaces as solidified particles which can manually be removed later. The end result is a liquid solder heating medium from which all flux particles have been removed. This solder heating medium is subsequently returned to the boiling equipment placed under the soldering chamber in which the solder heating medium is reheated.

The object of the invention can also be achieved by an apparatus as the one described in the second paragraph of this document. With this apparatus, pumping means are stopped during the soldering process, and started upon ending a solder process. The pumping means operate in a closed circuit starting at an outlet from the soldering process and ending at an inlet to the soldering process. The closed circuit may comprise at least a first heat exchanger operating at a first temperature, and at least a second heat exchanger operating at a second lower temperature, where the heat exchangers can be placed in conjunction with liquid collecting means.

In this way it can be achieved that the two condensation processes can take place in heat exchangers where the condensation does not necessarily take place with energy losses to the surroundings, because the energy delivered from the heat exchangers can be used in the soldering process for preheating of printed circuit boards before the boards enter the soldering zone. This preheating is necessary for avoiding temperature shocks during the soldering process.

A protective gas may be mixed with the vapour during the soldering process. The presence of a protective gas reduces oxidation during the soldering process. As is known, oxidation may occur not only on the soldering material but also the in the evaporated flux. Oxidation is undesirable because it often leads to the formation of carbon particles. Likewise, the presence of protective gas prevents the components on the printed circuit boards from being oxidized during the soldering process. The use of the protective gas could also lead to the use of a soldering paste containing only a very limited amount of flux. In the future it should also be possible to perform entirely flux-free soldering if the soldering takes place in an environment with protective gas.

The closed circuit may also comprise at least one heat exchanger for heating protective gas to a temperature below the condensing temperature of the vapour before the protective gas is returned to the soldering device in a time periods after soldering is finished. Preheating of the protective gas is important in order to avoid temperature shocks on printed circuit boards. Especially ceramic capacitors are very sensitive to large temperature fluctuations, and cracks in the ceramics can change to capacitors to resistors in a few hours. However, by heating the protective gas to 150°C for example, the temperature shock is reduced to less than 50°C. However, this temperature is sufficiently low for condensation of the vapour of the solder heating medium. Thus by pumping in preheated protective gas in a rather fast manner, the vapour is removed in only a few seconds.

Liquefied solder heating medium can be returned from the liquid collecting means through a conduit to a flux trap comprising steps, which flux trap is cooled by cooling means to a first condensation temperature and further cooled to a second lower temperature for flux liquefying. By using a flux trap made of a large number of small steps, the temperature can be reduced from step to step. The liquid solder heating medium passes the steps, and the temperature is gradually reduced. In this way the content of liquid flux is solidified and by forming the steps at a negative angle, liquefied particles will be collected in the steps and can later be mechanically removed by cleaning of the equipment. Depending on the kind of flux used, the temperature can be reduced to a very low level, maybe as low as 20°C, but because of the necessary reheating of the medium, the temperature will be reduced to exactly the temperature at which all the flux is liquefied, thereby saving energy.

The heat exchangers may comprise cooling fins that are tilted against the inlet direction in order to return liquefied solder heating medium and liquefied or solidified flux, in which the protective gas can pass over and around the fins. The tilted position of the fins is efficient for collecting heavy flux particles whereby small drops of flux heat the fins by which the fins are further cooled, and liquid flux flows downwards on the fins opposite the flow direction. From the fins, the flux can fall down as droplets. The surface of the fins can be made in such a way that there are no fixation points at all for liquid flux to adhere to so that the liquid flux will automatically start flowing

backwards by way of gravity as soon as droplets exceeding a certain size are formed. Thus the fins are self-cleaning.

Liquefied solder heating medium and liquefied or solidified flux can pass through filter means before reaching collecting means, which filter means can collect liquid or solidified flux and other chemical substances. By letting all the liquids that leave the heat exchangers pass through filters, a large part of the flux will be collected in these filters, and the filters can afterwards be cleaned and reused in the soldering machine.

Liquid solder heating medium can be collected at the surface of a tray placed under the soldering zone and led over the flux trap. Here by is achieved that also flux that has reached the boiling tray under the soldering zone can be collected in the flux trap. Liquid solder heating medium is pumped to the flux trap in periods the flux trap has free capacity, whish occur in periods between solder processes. After passing the flux trap the solder heating medium is returned to the tray where heating elements are heating the solder heating media for forming vapour.

Surfaces on elements in contact with flux might be coated with a material having ability not to fix liquid or solidified flux. In this way flux is removed from the surfaces primarily by liquid solder medium flowing back passing the liquid trap or the flux is ending in the tray under the soldering zone, and from here the solder heating medium is colleted and led over the flux trap.

The invention is described in more detail below with reference to the accompanying drawing in which

Fig. 1. shows a cross-section of a soldering zone comprising a device according to the invention,

Fig. 2 shows a partly opened top view of a soldering zone comprising a device according to the invention,

Fig. 3 schematically shows a flux trap.

Fig. 1 shows a cross-section of a soldering zone 2 having a tray (not shown) below the soldering zone and comprising heating elements for evaporation of medium 4 that evaporates and forms a vapour 6 that partly fills the soldering zone. The soldering zone comprises a conveyor belt 8 on which a device 10, e.g. a printed circuit board, is seen. The soldering zone is limited by the doors 12 and 14 which are shown as being closed, and at the bottom of the soldering zone, a steam valve 16 is shown which valve 16 in an open state forms a large number of small holes which open passage of vapour generated from the boiling liquid below. Above the steam valve 16, a screen 18 has been placed, primarily for collecting components falling off from printed circuit boards 10 during the soldering process. In order not to contaminate or destroy the valve 16, a closed circuit 20 for purifying the vapour 6 is provided. The closed circuit 20 comprises an inlet 22 connected with at least one tube 24 leading to a flange 26 from which the vapour 6 and flux or other gasses 60 enters a chamber 28 where a first condensing unit 30 is placed. Below the unit 30 a filter screen 32 is placed for collecting liquefied or solidified particles. Further in the flow direction of the vapour 6 and flux or other gasses 60 a second condensing unit 34 is placed. Below this condensing unit 34 a filter screen 36 is placed for collecting liquid or solidified particles. Further in the flow direction of the vapour 6 or gases, a heating element 38 is placed, which element is formed in the same way as the condensing units. Below the heating element 38 a filter screen 40 is placed for collecting liquid particles. After passing the heating element 38, gases enter a chamber 42 from which a tube 44 leads to a blowing unit 46 which blowing unit returns gases 60 to the soldering zone via an inlet 48. The condensing units 30 and 34 can be made as heat exchangers 50 and 52. The heating element 38 can also be made as a heat exchanger 54. The vapour 6 can be mixed with a protective gas 60 which passes through the whole unit 20 mixed up with the content of vapour, flux and other gasses. The heat exchanger 50 and 52 may comprise cooling fins 62 and 64 tilted against the flow direction. The heat exchanger 52 also contains fins 66 tilted against the flow direction. The surfaces in contact with the solder heating media can be coated with a material which having ability not to fix liquid or solidified flux.

In operation, a printed circuit board 10 is heated by evaporated solder heating medium 4 forming a vapour 6. During the soldering process, the blowing means 46 are not in operation. Thus vapour 6 rises from the underlying tray where a heating element is in operation for producing the vapour 6. At the beginning, the vapour 6 will condense when contacting the printed circuit board 10, but this condensation leads to a temperature rise on all the surfaces of the printed circuit boards 10 up to a temperature at which the soldering process takes place. When the soldering process is completed, which takes only a few seconds after reaching the correct temperature, a blower unit 46 is started, and protective gases 60 are led into the chamber. The gases have a temperature below the condensation temperature of the vapour 6. This leads to rapid condensation of vapour 6 which drops down on the steam valve 16 through which it passes as a liquid to the tray below. A large part of the vapour 6 is discharged through the outlet 22 and the tube 24, and led into the chamber 28 where the vapour passes through the condensing units 30 and 34. The content of evaporated flux and vapour 6 is totally condensed when it has passed these two condensation units 30 and 34, but the protective gas 60 continues through the heating element 54 and is preheated before it is once again sent through the blowing unit 46. Not until the major portion of the vapour 6 has been removed from the soldering chamber, are the printed circuit boards 10 removed through a door 12 that can be opened. Afterwards another door 14 can be opened and the next printed circuit board 10 can be led into the soldering zone. In practice, depending on the sizes of the printed circuit boards 10, several boards 10 can be soldered simultaneously in the soldering zone.

Fig. 2 shows the closed circuit 20 seen from above. Inlet tubes 24 are shown at the top of the figure together with inlet flanges 26 leading to the inlet chamber 28 containing a mixture of vapour 6 and protective gas 60. Afterwards this mixture of gasses passes through the condensing unit 30. Below the condensing unit 30 a filter screen 32 is placed. Further in the flow direction of the gas, a second condensing unit 34 is placed below which a filter screen 36 is placed. The gas is led through the heating element 38 below which a filter screen 40 is placed. The protective gas 60 enters the chamber 42 from which conduits 44 lead to blowing units 46.

Fig. 3 shows a closed circuit 120 containing a vapour 106 and a protective gas 160. At the bottom a collector tray 156 is placed from which an outlet 158 leads to a flux trap 122 comprising steps 124 where vapour 106 after condensation forms solder heating liquid 104 which flows over the steps 124 of the trap to an outlet 128 where the entire trap is cooled by cooling means 126, where the now cooled and purified solder heating medium 104 via an outlet 130 is returned to the soldering zone. In the flux trap 122 liquid fluxes is heavier than the liquid solder heating media, and the flux is mostly flowing under the liquid solder heating media 4, where the flux is in contact with the steps 124. Flowing down the steps the temperature of the steps 124 is decreased downwards, and the flux is solidified during the passage of the steps 124, but solidified flux is forming glue which is retracted to steps 124. A cleaning of the steps 124 is necessary as part of normal maintains of the soldering machine.

CLAIMS

1. A method for flux deposition in conjunction with vapour phase soldering, where a solder heating medium (4) is evaporated by heating, thereby forming a vapour (6), which vapour (6) heats elements to be soldered partly by condensation to a temperature above a soldering temperature, which lead to soldering of elements (10), which soldering process leads to evaporation of flux and other chemical substances, **characterized in that** vapour (6) of solder heating medium (4) containing flux and other chemical substances is drawn into a closed circuit (20) in time periods between or after soldering processes, where the closed circuit comprises at least a first condensation process (30) and a second condensation process (34), which first and second condensation processes (30, 34) take place at a first high temperature and at a second lower temperature, and liquid solder heating medium (4) is returned to the vapour phase soldering process.

2. A method according to claim 1, **characterized in that** the first temperature depends on the condensation temperature of the flux, where the second temperature depends on the condensation temperature of the solder heating medium (4).

3. A method according to claim 1 or 2, **characterized in that** the method comprises the use of a protective gas (60) during the soldering process, which protective gas is mixed with the vapour (6).

4. A method according to one of the claims 1-3, **characterized in that** the protective gas (60) is heated by heating means (38) to a temperature below the condensation temperature of the vapour (6) after it has passed through the condensing processes (30, 34) and before the protective gas is returned to the soldering chamber, which condensing processes (30, 34) and the heating process (38) take place in time periods after soldering of the elements (10).

5. A method according to one of the claims 1-4, **characterized in that** the condensed heating medium (4) is returned to the process in that it is led through a flux depositing

trap (122), which trap (122) comprises a cooling process for flux condensation and flux solidification.

6. An apparatus (20) for flux deposition, connected to a soldering machine (2), which soldering machine comprises a solder heating medium (4) evaporated by heating means forming a vapour (6) that heats elements to be soldered by heat transfer and by condensation, which apparatus (20) comprising means for condensation (30, 34) of a vapour (6) containing flux where pumping means (46) circulate vapour (6) containing flux through the condensation means (30, 34), where the condensation means (30, 34), comprise a heat exchanger (30, 34) for cooling the vapour (6) for flux condensation, **characterized in that** the pumping means (46) are stopped during the soldering process, and started upon ending a solder process, where the pumping means (46) operate in a closed circuit (20) starting at an outlet (22) from the soldering process and ending at an inlet (48) to the soldering process, where the closed circuit (20) comprises at least a first heat exchanger (50) operating at a first temperature, and at least a second heat exchanger (52) operated at a second lower temperature, where the heat exchangers (50, 52) are placed in conjunction with liquid collecting means (56).

7. An apparatus according to claim 6, **characterized in that** a protective gas (60) is mixed with the vapour (6) during the soldering process.

8. An apparatus according to claim 6 or 7, **characterized in that** the closed circuit (20) also comprises at least one heat exchanger (54) for heating protective gas (60) to a temperature below the condensing temperature of the vapour (6) before the protective gas (60) is returned to the soldering device in a time periods after soldering is finished.

9. An apparatus according to one of the claims 6-8, **characterized in that** liquefied solder heating medium (4, 104) is returned from the liquid collecting means (56, 156) through a conduit (58, 158) to a flux trap (122) comprising steps (124), which flux trap (122) is cooled by cooling means (126), first to a temperature for condensation and subsequently further cooled to a temperature for flux liquefying.

10. An apparatus according to one of the claims 6-9, **characterized in that** the heat exchangers (50, 52) comprise cooling fins (62, 64) that are tilted against the inlet direction in order to return liquefied solder heating medium (4) and liquefied or solidified flux, where protective gas (60) passes over and around the fins (62, 64).

11. An apparatus according to one of the claims 6-10, **characterized in that** liquefied solder heating medium (4) and liquefied or solidified flux passes filter means (32, 36) before reaching collecting means (56), which filter means (32, 36) collect liquid or solidified flux and other unwanted chemical substances.

12. An apparatus according to one of the claims 6-11, **characterized in** that liquid solder heating medium is collected at the surface of a tray placed under the soldering zone and led over the flux trap (122).

13. An apparatus according to one of the claims 6-12, **characterized in** that surfaces on elements in contact with flux (30, 34, 38, 56, 62, 64, 66, 122, 124) is coated with a material having ability not to fix liquid or solidified flux.

ABSTRACT

The present invention relates to a method and an apparatus for flux deposition in conjunction with vapour phase soldering, where a solder heating medium is evaporated by heating, thereby forming a vapour, which vapour heats elements to be soldered, partly by condensation to a temperature above a soldering temperature, which leads to soldering of elements, which soldering process leads to evaporation of flux and other chemical substances. It is the object of the invention to remove flux from a vapour phase solder furnace without losing solder heating medium. This can be achieved by a method as described in the introduction, which method is modified in such a way that vapour of solder heating medium containing flux and other chemical substances is drawn into a closed circuit in time periods between and after soldering processes, where the closed circuit comprises at least a first condensation process and a second condensation process, which first and second condensation processes take place at a first high and a second lower temperature, and liquid solder heating medium is returned to the vapour phase soldering process. Hereby it can be achieved that after completion of a soldering process where e.g. a printed circuit board has been fully soldered, the flux, which was contained in the soldering paste placed on the board, to a large extent is evaporated and consequently mixed up with the solder heating medium, and thus removed from the process.

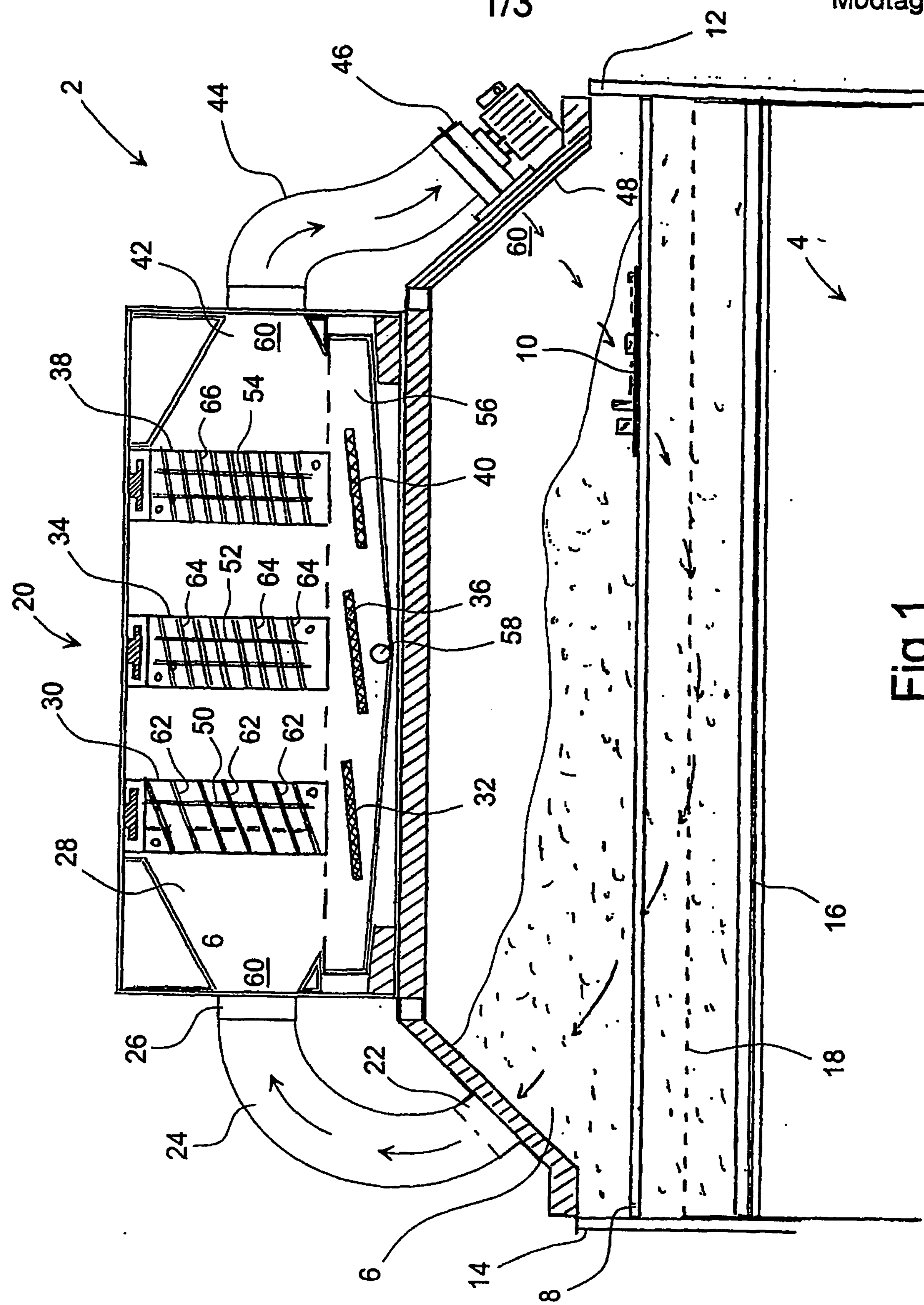
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Fig.1

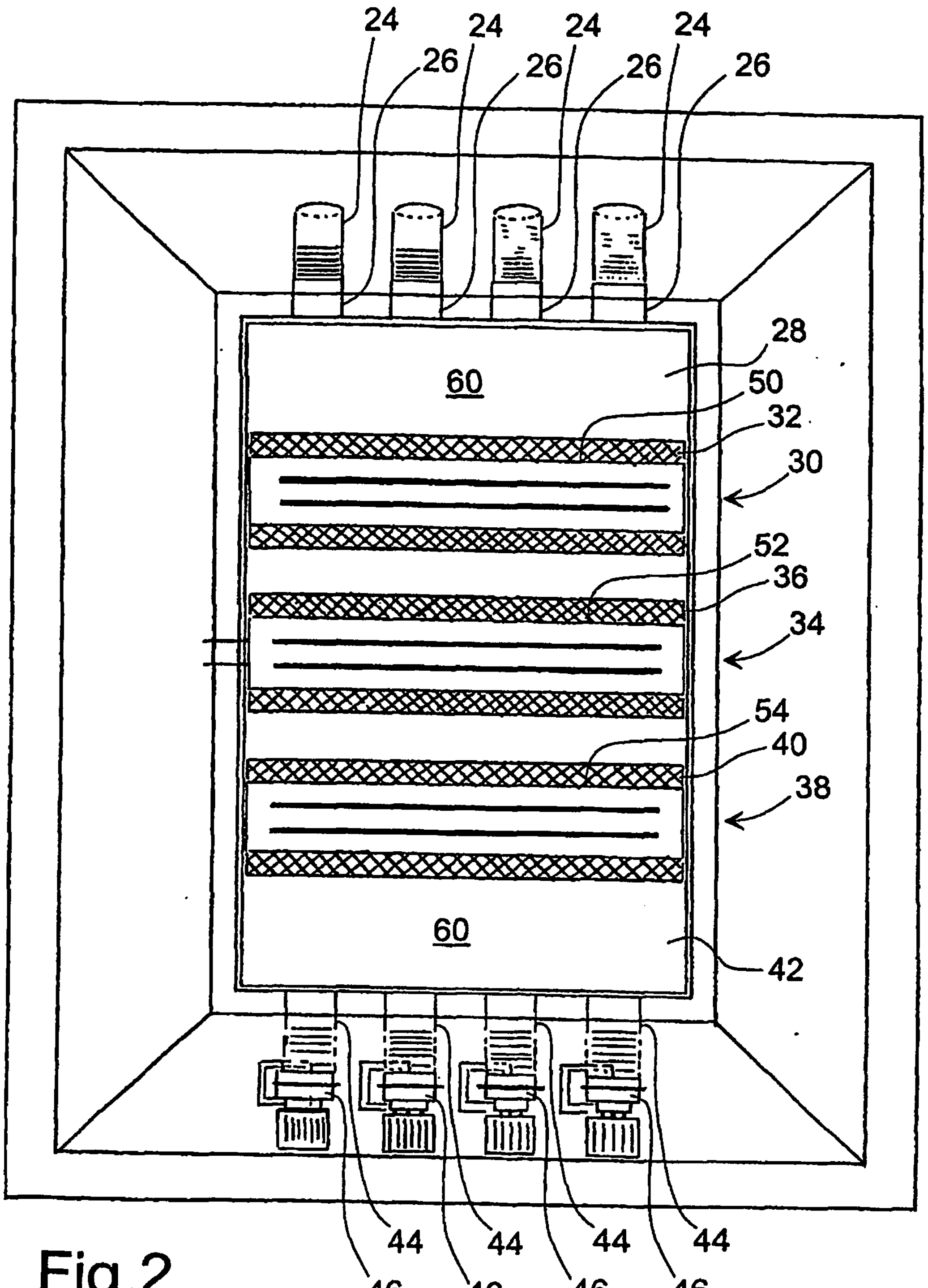
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Fig.2

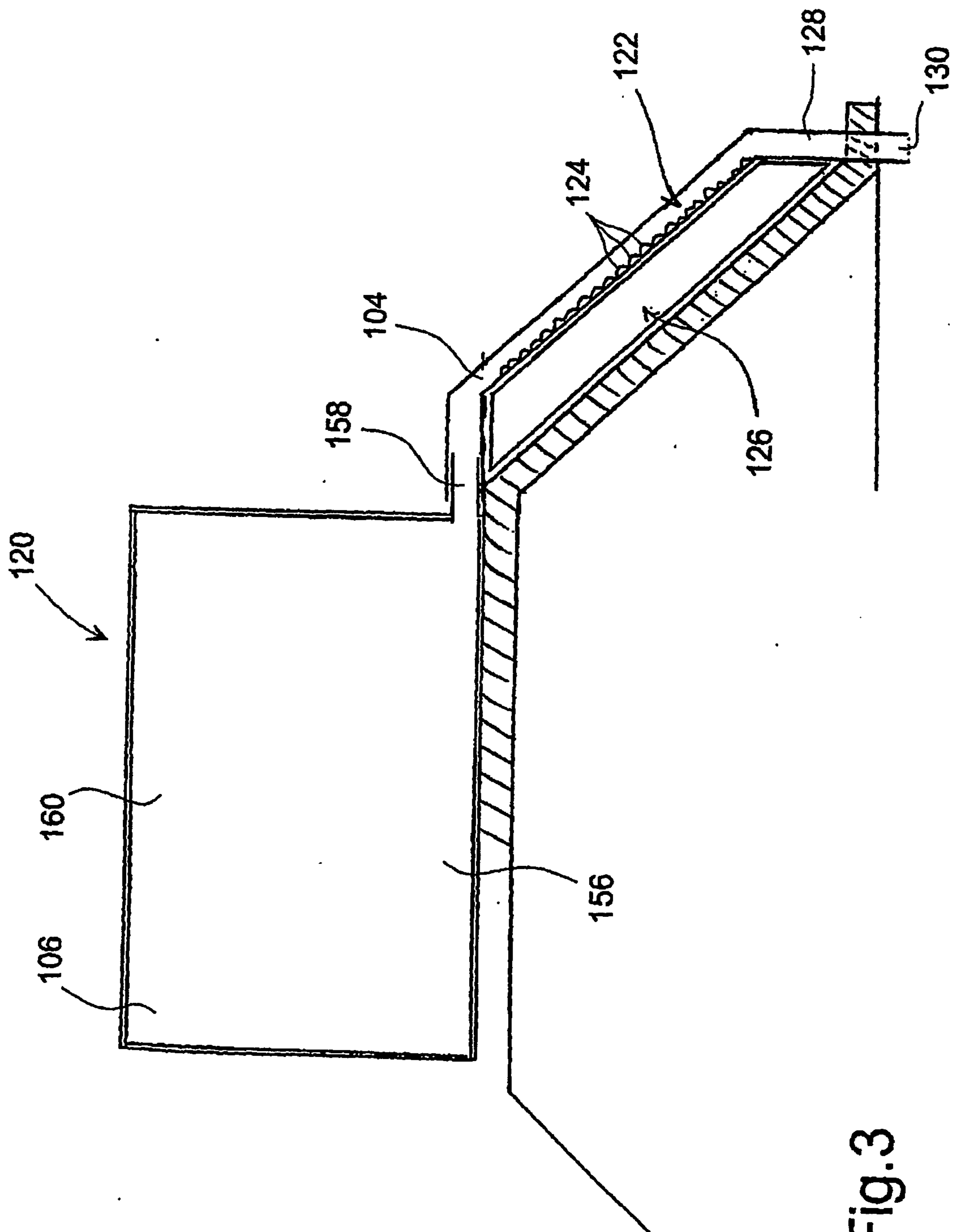

Fig.3